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BACHELOR THESIS

Growth opportunities and financing of renewable energy in Germany and Czech Republic

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Abstract

According to Directive 2009/28/EC overall share of RES in EU energy consumption must be 20% and 10% in transport consumption. The 2020 target for Germany is 18% and for the Czech Republic is 13%. The major financial supporting schemes in the Czech Republic and Germany include feed-in tariffs and green bonuses. Likewise, we propose some ways to resolve some flaws of RES, such as intermittency character of RES, free-rider problem in case of quota obligations scheme etc. Though European Commission approved the shift from FIT scheme towards auction scheme, we analyse the dependence between FITs and installed capacities of RES. As a result of this analysis we obtained optimum intervals of FITs for some types of RES.

JEL Classification	G32, L94, L51, O44, Q28.
Keywords	Renewable energy, feed-in tariff, Czech renewables, German Renewables

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Acronyms

CZK Czech koruna

DSO Distribution System Operator

EEG German Renewable Energy Act (ger. Erneuerbare-Energien-Gesetz)

ETS European Emissions Trading System

EUR Euro

FIT Feed-in tariff

hettest Breusch-Pagan test for heteroskedasticity

ktoe kilotonne of oil equivalent

kW kilowatt

kWh kilowatt-hour

kWp kilowatt peak

MW megawatt

NREAP National Renewable Energy Action Plan

ovtest Ramsey RESET test

PV Photovoltaic

RES Renewable Energy Source

RES-E Renewable energy sources in electricity or electricity from renewable energy sources

RES-H/C Renewable energy sources in heating and cooling or heating and cooling from renewable energy sources

RES-T Renewable energy sources in transport

swilk Shapiro-Wilk W test for normal data

TSO Transmission System Operator

VAT Value-added tax

Bachelor Thesis Proposal

Author	Sabyrzhan Tyuleubekov
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Proposed topic	Growth opportunities and financing of renewable energy in Germany and Czech Republic

Topic characteristics European Commission created the Renewable energy directive that requires all EU countries to generate 20 percent of energy from renewable sources by 2020 and 10 percent of their transport fuels come from renewable sources by 2020.

There are two major policies for promoting renewable energy generation in the EU: feed-in-tariffs (FITs) and quota obligations. Naturally, such policies create distortions in the energy market. Furthermore, in April, 2014 European Commission approved the removal of all FIT support mechanisms for RES effective from 2017 and shift towards auction mechanism. We will examine how size of FITs induce investors to install capacities of RES in the Czech Republic and Germany based on empirical data. And will try to find intervals for optimum FITs.

Hypotheses At this early stage of my research, there are several questions, which could be potentially answered in the thesis. First, we want to determine the relation between greenhouse gas abatement and RES share in heating and cooling, electricity and transport. Secondly, we want to find intervals for feed-in tariffs at which annual installed capacities are maximized.

Methodology We will run three regressions where dependent variables will be GHG abatement by the means of RES-H/C, RES-E and RES-T and independent variables will be share of RES-H/C, RES-E and RES-T respectively. Likewise, we will run various regressions on annual installed capacities where feed-in tariffs and/or their polynomials will act as independent variables.

Outline

1. Introduction
2. Literature review
3. Overview of existing Germany and Czech renewable energy policies
4. Methodology and model
5. Empirical data analysis
6. Outcome
7. Conclusion

In the first part of the thesis, we will review existing prominent policies of promotion renewable energy sources in the Czech Republic and Germany. Then, we will review critique of policies in these countries. After that, we will run various regressions and define the optimum intervals for FITs. Finally, we will summarize the outcomes of the regressions and conclude.

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Author Supervisor

Chapter 1

Introduction

On April 23, 2009 European Commission published so-called the Renewables Directive, official title – Directive 2009/28/EC. This directive mandated all the Member States to achieve certain level of renewable energy sources in final consumption by 2020. Overall share of RES in EU energy consumption must be 20% and 10% in transport consumption. The 2020 target for Germany is 18% and for the Czech Republic is 13%.

The major financial supporting schemes in the Czech Republic and Germany include feed-in tariffs and green bonuses, these schemes are reviewed in Sections 2.1.1 and 2.2.1. Feed-in tariff scheme is widely criticised because of its excessive costs, this critique is reviewed in section 3.1. As a result of this and due to other reasons on April 9, 2014 European Commission approved the shift from all FIT support mechanisms towards auction scheme for RES effective from 2017.

In Chapter 2, we summarize support schemes and targets in Germany and the Czech Republic by reviewing National Renewable Energy Action Plans and briefly review other existing policies for promotion of RES. Chapter 3 reviews critique of RES in literature and also includes the analysis of greenhouse gas emissions abatement by the means of RES. Chapter 4 describes the model we use and the outcomes of the model. Finally, we conclude.

Analysis of greenhouse gas emissions abatement is done with the use of econometric tools. We run the regressions of GHG abatement by the means of RES-E, RES-H/C and RES-T on RES-E, RES-H/C and RES-T share in final gross consumption respectively. In addition, we estimate GHG abatement for 2020.

The model in Chapter 4 is going to analyse how FITs and installed capacities of RES are correlated. Therefore, we will try to find the optimum intervals of FITs for each type of RES by analysis of empirical data. We are not analysing actual generation of energy by RES, since it is dependent on weather conditions and etc. i.e. factors which are hardly can be controlled. Likewise, we are not analysing the results of auctions already held in Germany, since there is no enough data in order to draw some conclusions, nonetheless some summary about this scheme is provided in Section 2.3. Thereby, the optimum intervals we found can be used until 2017, unless European Commission will not postpone the removal of FIT support mechanisms. Moreover, FITs inside the optimal intervals do not minimise overall costs of supporting RES, they are indicating FITs values at which installed capacities of RES can be maximised.

Chapter 2

Overview of existing policies

2.1 German National Renewable Energy Action Plan

The latest issue of German National Renewable Action Plan (hereinafter German NREAP) was published in July 2010.

RES-E generation increased fivefold from 17 TWh in 1990 to 93 TWh in 2009 (all numerical data in this section is taken from German NREAP, if not stated otherwise). In addition, composition of RES-E changed dramatically, in 1990, 91% of RES-E was generated by hydropower, while in 2009 40% of RES-E was generated by wind power, 33% by biomass and only 20% by hydropower.

RES-H/C generation increased from 32 TWh in 1990 to 115 TWh in 2009, main portion generated by biomass.

As all NREAPs, the German one has its projections of gross final consumption of energy until 2020.

Table 2.1: Expected gross final consumption of energy in Germany in the areas of heating and cooling, electricity and transport until 2020, taking into account the impact of energy efficiency and energy saving measures 2015-2020 (ktoe)

	2015	2016	2017	2018	2019	2020
Heating and cooling	103588	101581	99551	97449	95276	93139
Electricity	50588	50229	49799	49346	48844	48317
Transport	51279	50655	50034	49414	48857	48302
Gross final consumption	213122	210089	206984	203760	200463	197178

Source: National Renewable Energy Action Plan of Germany

We can see from the Table 2.1 that Germany will gradually decrease its gross final consumption. The biggest decline, decrease of 10%, is expected in heating and cooling sector due to increased efficiency.

Directive 2009/28/EC sets the 2020 target level of renewable energy in gross final energy consumption of 18% for Germany. Whereas, German NREAP estimates that by 2020 share of RES in gross final energy consumption will be 19.6%. In the electricity sector RES will account for 38.6%, in the heating/cooling sector RES will account for 15.5% and in the transport sector RES will account for 13.2%. German NREAP has its estimated trajectories of renewable energy in aforementioned sectors. These estimations will be used as a reference in the following assumptions and computations.

Table 2.2: Estimated trajectory of energy from renewable sources in heating and cooling, electricity and transport 2015-2020 in Germany

	2015	2016	2017	2018	2019	2020
RES-H/C (%)	11.7	12.4	13.1	13.9	14.7	15.5
RES-E (%)	26.8	28.8	31.0	33.3	35.9	38.6
RES-T (%)	7.0	7.1	9.3	9.4	9.7	13.2
Overall RES share (%)	13.5	14.4	15.7	16.7	17.7	19.6

Source: National Renewable Energy Action Plan of Germany

There are a lot of policies and measures for promotion of renewable energy mentioned and described in German NREAP, we will describe the ones concerning feed-in tariffs and other financial support schemes. The full list of the core measures can be found in Table 5 of German NREAP.

In Germany, there is a federal law, the Renewable Energies Heat Act (EEWarmeG), which requires all new buildings to cover heat energy needs of at least 15% by solar thermal energy, 30% by biogas or 50% by liquid or solid biomass, heat pumps or geothermal energy. However, no federal law exists regarding use of RES in existing buildings. Nevertheless, such laws can be implemented by federal states.

Major legislative instrument for promotion RES in Germany is the Renewable Energy Source Act (hereinafter EEG). It came in force on April 1, 2000. The EEG includes many regulations regarding grid connections such as priority grid connection for producers of RES-E and compensation schemes such as feed-in tariffs and etc.

In case of disputes between RES producers and grid operators, there is a neutral body for resolving them – The Clearing House EEG. The costs regarding a grid connection, optimization, expansion and development are borne by the grid operator. Some part of the costs is recovered by grid fees. Moreover, producers of RES-E are not charged transmission and distribution tariffs.

2.1.1 Financial support schemes

There are different financial support schemes:

(a) Feed-in tariff – all RES-E plants with capacity up to 500 kW and in accordance with EEG can be entitled with FITs. Producers of RES-E are guaranteed with FITs for 20 years, with exception of large hydropower plants, they are guaranteed for 15 years, plus the year of putting into operation. FITs are paid by grid operators, who are obliged to buy all electricity from RES-E producer, to producers. However, these additional costs are passed onto end customers via TSOs and DSOs and end customers have them included in their bills. Feed in tariffs are technology specific, they can be found in the Table 2.3.

Table 2.3: German feed-in tariffs as of 11.12.2014

Type of RES	Feed-in tariff EURcent/kWh
Hydropower	3.50 - 12.52
Biomass	5.85 - 23.73 minus 0.2 per kWh
Biogas	5.83 - 27.73 minus 0.2 per kWh
Wind power plant	Onshore: 4.95 - 8.90 minus 0.4 per kWh Offshore: 3.9 - 19.4 minus 0.4 per kWh
Geothermal power plant	25.2 minus 0.2 per kWh
Photovoltaic power plant	specific building-mounted systems: 11.49 - 13.15 minus 0.4 per kWh other systems: 9.23 minus 0.4 per kWh up to 10 kW: 12.59 up to 40 kW: 12.25 up to 500 kW: 10.95 up to 10 MW: 8.72

Source: RES LEGAL

There is a cap for PV plants of 52 000 MW which are entitled for FITs. No caps for other technologies have been introduced. Additionally, Germany has introduced degression rates, i.e. FITs will decrease annually for some percentage thus inducing producers to reduce costs. Degression rates can be found in Table 2.4.

Table 2.4: Degression rates for German FITs

Type of RES	Degression rate
Hydropower	0.5% every year
Biomass	0.5% every 3 months and if biomass surpasses 100 MW degression rate go up to 1.27%
Biogas	Landfill and sewage gas: 1.5% Other: 0.5% every 3 months and if biogas surpasses 100MW degression rate go up to 1.27%
Wind	Onshore: 0.4% every 3 months and if power surpasses 2600 MW degression rate go up to 1.2%. If power goes below 2400 MW the degression rate decreases and in extreme cases FITs even increased. Offshore: until 1.1.2018 no degression rate imposed, then degression rate will be between 0.5% and 1.0%
Geothermal	5% every year from 2018
Photovoltaic	0.5% every month if power surpasses 2600 MW degression rate go up to 2.8%. If power goes below 2400 MW the degression rate decreases and in extreme cases FITs even increased by up to 1.5%

Source: RES LEGAL

(b) The KfW[1] Financing Initiative Energiewende – this scheme provides with low-interest loans for investments in installations of RES-E in accordance with EEG. The loan can cover up to 50% of the project and can be between EUR 25 million and EUR 100 million. The loan is long-term and interest period is up to 20 years, in addition, first 3 years can be repayment-free. Interest rates depend on the situation on capital markets but are fixed for 10 years, for loans exceeding 10 years interest rates are redefined. Energy supply companies cannot get loans under this programme. Only companies with annual turnover between EUR 500 million and EUR 4 billion are eligible for this programme.

(c) The KfW Programme Geothermal Exploration Risk – this programme is eligible only for geothermal energy. It covers investments costs of drilling activities, the loan can cover maximum 80% of the costs. There is a cap of EUR 16 million per drilling. The loan is given for 10 years with first 2 repayment-free years.

(d) The KfW Programme offshore wind energy – this programme is eligible

[1]KfW is a German state-owned development bank, which provides financial aid for renewable energy projects

only for companies that want to construct wind farms inside 12 nautical-mile zone of the North and Baltic Sea. There are three different forms of financing: (i) direct loans under financing by bank syndicates; (ii) financing package combining a KfW on-lent through a bank loan and a direct loan from KfW; (iii) in addition to (i) and (ii), a direct loan under bank syndicates is granted covering unforeseen costs during construction phase.The loans are long-term and interest period is 20 years with first 3 repayment-free years. Interest rate is redefined after 10 years.

(e) The KfW Renewable Energy Programme Premium – this programme is eligible only for producers of electricity from geothermal energy. Loans cover up to 80% of investment costs. Loans can be given for 5,10 or 20 years with first 1,2 and 3 repayment-free years respectively. Interest rates are fixed for 10 years and then redefined if loan is for 20 years.

(f) The KfW Renewable Energy Programme-Standard – this programme is eligible for investments in any RES technology. Loans can be given to projects even if they are not to be constructed in Germany but close to German borders and moreover even if project is done abroad but by German company. Loan can cover up to 100% of investment costs, nevertheless there is a cap of EUR 25 million per project. The loan is long-term and low-interest with fixed interest periods of 5 or 10 years including the repayment-free period. Effective interest rates may vary between 1.31% and 7.56% per annum. The fixed interest loan can be granted for 20 years if economic and technical duration of investment is longer than 10 years.

(g) Market premium – all technologies of RES are entitled for market premiums. Market premium is granted usually for 20 years plus the year of putting into operation. Market premiums are paid by grid operators, who are obliged to purchase all generated electricity. However, these costs, identically as in FITs scheme, passed onto end customers and they have these costs in their bills. The amount of market premium is calculated every month by subtracting the monthly electricity value in EURcent/kWh from the reference tariff (which can be found in Table 2.3). The scheme is identical to FITs with only difference – plants with installed capacity exceeding 500 kW are eligible for this scheme.

(h) Flexibility premium – only biogas plants that are put into operation before August 1, 2014 are eligible for this support. Subsidy is provided only for additional capacity for on-demand use. The amount of the subsidy is EUR 130 per additionally installed kW per year for 10 years. The subsidies will be provided until 1.350 MW of additional capacities will be reached. The additional costs are borne by end customers.

(i) Flexibility surcharge – same plants eligible as for flexibility premium. This subsidy can be combined with market premium or feed-in tariff. Flexibility surcharge amounts for 40 euro per installed kW per year for duration of eligibility of market premium or FIT. Additional costs are borne by end customers.

It is stipulated in the EEG that electricity, which gets feed-in tariff, cannot be marketed as "green electricity". Nonetheless, it is possible for producers of RES-E to get simultaneously FITs and low-interest loans.

In 2009, the use of domestic renewable energy sources prevented 108 million tons of CO2 equivalents of energy related greenhouse gas emissions. EUR 5.7 billion of energy imports were saved. The total turnover from renewable energies was EUR 33.3 billion, EUR 17.6 billion in new construction and development of installations for RES and EUR 15.7 billion in other renewable energy plant operations.

Germany has 300 000 employees in renewable energy industry, this is 75% higher than in 2004. Furthermore, Germany anticipates 400 000 people to be employed in renewable energy sector by 2020. Also, 215 million tones of CO2 emissions to be prevented by 2020 through the use of RES.

2.2 Czech National Renewable Energy Action Plan

Ministry of Industry and Trade of the Czech Republic published the latest issue of Czech National Renewable Energy Action Plan (hereinafter Czech NREAP) in August 2012.

As all NREAPs, the Czech one has its projections of gross final energy consumption until 2020.

From the Table 2.5 it is seen that unlike Germany, Czech Republic does not expect a decline in gross final energy consumption. Only a little decrease is anticipated in heating and cooling sector.

Directive 2009/28/EC sets the 2020 target level of renewable energy in gross final consumption of 13% for the Czech Republic. Whereas Czech NREAP targets 14% of gross final consumption to come from renewable energy sources

Table 2.5: Expected gross final energy consumption of the Czech Republic in heating and cooling, electricity and transport up to 2020 taking into account the effects of energy efficiency and energy saving measures 2015 - 2020 (ktoe)

	2015	2016	2017	2018	2019	2020
Heating and cooling	16 812	16 739	16 667	16 638	16 600	16 586
Electricity	6 328	6 425	6 520	6 616	6 712	6 810
Transport	6 436	6 453	6 470	6 453	6 437	6 407
Gross final consumption	29 576	29 617	29 657	29 708	29 748	29 803

Source: National Renewable Energy Action Plan of the Czech Republic

by 2020. Czech NREAP has its estimated trajectories of renewable energy in heating and cooling, electricity and transport.

Table 2.6: Estimated trajectory of energy from renewable sources in heating and cooling, electricity and transport 2015–2020 in the Czech Republic

	2015	2016	2017	2018	2019	2020
RES-H/C (%)	13.6	14.0	14.5	14.8	15.2	15.5
RES-E (%)	12.8	13.0	13.2	13.4	13.5	13.5
RES-T (%)	7.1	7.7	8.3	9.6	10.2	10.8
Overall RES share (%)	12.0	12.4	12.8	13.3	13.7	14.0

Source: National Renewable Energy Action Plan of the Czech Republic

There are a lot of policies and measures for promotion of renewable energy mentioned and described in Czech NREAP, we will only describe the ones regarding feed-in tariffs and feed-in premiums (so called green bonuses). The full list of all policies and measures for promotion of renewable energy mentioned in Czech NREAP can be found in Table 5 of Czech NREAP.

It is highlighted that the Czech Republic has "Complex legislation (one of the most complex in the EU)" regarding authorization and other permissions prior to the construction of renewable energy plants. The preparation and implementation phase takes between 122 and 196 months.

According to the Act No. 165/2012 TSOs and DSOs are required to connect producer of RES to the grid if producer requests and complies with the connection conditions.

2.2.1 Financial support schemes

In the Czech republic there are three types of financial support for RES:

(a) Investment support from subsidy schemes for the promotion of renewable energy and heat production

(b) Feed-in tariffs and feed-in premiums - this type will be discussed later

(c) Tax exemptions and tax refunds

Tax exemptions and tax refunds, pursuant to the Act No. 586/1992 on income tax, are attributable to:

- Small water power plants up to the capacity of 1 MW,
- Wind power plants,
- Heat pumps,
- Solar installations,
- Installations generating and using biogas and woodgas,
- Biomass energy or heat generating installations,
- Installations generating biologically degradable substances as specified in a special legal regulation.

Tax exemptions last for first five years of operation plus the year of putting into operation.

Feed-in tariffs and green bonuses are part of so-called operational support. These two schemes of support cannot be combined, however producers may switch from one to another once a year.

The Energy Regulatory Office taking into account the industrial producer price index recalculates feed-in tariffs annually. Feed-in tariffs are guaranteed for a lifecycle of a renewable energy plant, which is usually 20 years.

Green bonuses are guaranteed only for one year, and then reassessment by the Energy Regulatory Office is done.

The amount of green bonuses is determined by the Energy Regulatory Office basing on the market price of electricity. Producers can sell the generated electricity to the market and get a green bonus, likewise, producers can consume the generated electricity and get a green bonus for consumption of RES-E. From this perspective, green bonuses scheme is hedging producers from market prices fluctuations, since a green bonus is a markup to a market price of electricity.

Under feed-in tariff scheme, producers of RES-E can sell generated electricity to the mandatory purchaser who is obliged to pay the feed-in tariff and then the market operator pays the difference between the feed-in tariff and the market electricity price. In case of green bonuses, the market operator pays them to producers of RES-E.

There is a state subsidy to cover the costs of market operators associated with feed-in tariffs. This subsidy covers all support costs of heat and the remaining part covers support costs of electricity. If not all support costs of electricity are covered by the subsidy, then they are borne by end customers. The Energy Regulatory Office determines the nationwide uniform fee for end customers and the amount of the subsidy is determined by Ministry of Industry and Trade.

For feed-in tariffs not to be volatile, it is restricted to lower them more than by 5% per year and increase them more than by 15%. In addition, there is a cap on the amount of support for all forms of 4500 CZK per MWh.

Feed-in tariffs and green bonuses are technology-specific. Furthermore, feed-in tariffs and green bonuses are different for plants with different vintage (the year of putting into operation). Tariffs in the Table 2.7 are excluding VAT.

Table 2.7: Czech feed-in tariffs and green bonuses for 2014

Type of RES	Feed-in tariff	Green bonus
Reconstructed hydro from 1/1–31/12/2014	9.10	6.1
Hydro at new locations from 1/1–31/12/2014	11.80	8.8
Biomass	4.8-12.1	1.7-9.0
Biogas	12.9	9.8
Landfill, fermentation and mine gas	7.10	4.1
Wind	7.3	5.6
Geothermal	12	8.9
Photovoltaic	up to 5 kW: 11.10 up to 30 kW: 9.00	up to 5 kW: 8.9 up to 30 kW: 6.8

Source: RES LEGAL

In the feed-in tariff scheme there is a cap on installed capacity, the following plants are entitled to the feed-in tariffs

- Photovoltaic power plants up to 30 kWp[2],

[2]kilowatt peak

- RES other than photovoltaic power plants up to 100 kW,
- Wind power plants up to 10 MW.

In the green bonuses scheme there are no caps on installed capacity.

As a result of these support schemes prices for end customers increase, since additional costs of promotion of RES are borne by them.

Nonetheless, producers of RES-E cannot combine feed-in tariffs and green bonuses, but they can get different types of financial support simultaneously, e.g. obtain green bonuses and income tax exemptions. Also, producers of RES-E and RES-H/C get loans with lower interest rates.

As of renewable sources in heating and cooling, there are the following support schemes:

(a) Investment support from the European Union Structural Funds (Operational Programmes in Environment, Business and Innovation and the 2007–2013 Rural Development Plan),

(b) Exemption from property tax (pursuant to Regulation No. 12/1993),

(c) Direct operational support of generation of heat from RES by means of annual green bonuses resulting from Act No. 165/2012,

(d) Indirect support by means of a support of RES-H/C

2.3 Other existing policies

Quota obligations is a quantity based approach, whereas feed-in tariff scheme is a price based approach. In quota scheme, some fixed amount of sold electricity in the market has to be generated from RES. The amount of electricity from RES is determined for the whole state. After that, the amount is allocated among all operators. Thus, operators have to buy so-called green certificates or buy energy directly from producers of RES. Certificates are issued by RES-E generator and then RES-E producers can sell electricity at market prices plus separately sell green certificates. If produced electricity is sold without green certificate, it cannot be accounted by the buyer as green energy. So even if in fact electricity is generated from RES, it is not counted as green without the certificate, this fact may cause a free-rider problem, which will be discussed later.

Tradable certificates system induces suppliers of electricity invest more efficiently. For example, there is a fixed amount of RES-E to be sold q for supplier A and B, but supplier A is unable to generate required amount q by itself, it generates amount a, whereas supplier B can generate more than q, it generates amount b. So we have $a < q < b$. With existing tradable certificates market, supplier B can sell certificates for surplus electricity ($= b - q$) and supplier A can buy certificates for missing amount of RES-E ($= q - a$).

Therefore, suppliers choose by themselves whether to invest into RES-E installations or buy certificates in the market. Certificates system also induces technological innovation and competition between RES-E producers. Under quota system, investors will be more careful about their investments, i.e. they will examine the site of installation more as well as the selection of technology to use. So no PV installations will be made in areas where sun barely shines and so forth. However, this may hinder development of immature but promising technologies.

Under certificate system, free-rider problem may occur. For example, there are two suppliers N and S in the country. Supplier N operates in the northern region of the country and supplier S in the southern region. Supplier N produces energy solely from RES and supplier S uses only fossil fuels. Thus, supplier S meets quota obligation entirely by buying certificates from supplier N. Customers of supplier S will have to cover additional costs associated with purchase of these certificates, whereas customers of supplier N will not have these additional costs. Nonetheless, customers of supplier N will enjoy cleaner air and other benefits associated with RES at the expense of customers of supplier S. While customers of supplier S will not enjoy same (if any) portion of benefits associated with RES, since located in another region. This problem can be resolved by introducing a cap on purchasing of certificates from other regions. However, this can impede the liquidity of tradable certificates market.

Under such system, prices for certificates will be determined by the market itself. In order to avoid extreme prices price ceiling and price floor can be defined. Furthermore, in order to decrease volatility of certificate prices market for futures can be created. Menanteau et al. (2003) suggests to redistribute money collected from ones who was unable to meet the quota by reverse bidding system to producers-sellers of RES-E.

Renewable energy auctions is a hybrid of quantity-based and price-based approaches. Governments set the target of RES-E and producers of RES-E or project developers act as bidders. Thus, bidders bid a price per unit of electricity at which they will generate it. Then government assesses the bids on the basis of price and other criteria and signs a power purchasing agreement with the winner of the auction.

Auction scheme allows governments to design an auction according to their needs, thus governments can have more control over the sector and its development. Also, with the use of well-designed auctions the real price will be discovered. Since, it is a competitive process and bidders are induced not to inflate prices for the product, so they bid the real prices or at least close to real. Thus, excessive costs associated with support of RES should decrease, since more competition will induce producers to reduce their costs.

First auctions held in Germany revealed that FITs for PV plants are lower than actual costs faced by producers. The auction took place in April 2015 and the total capacity to be auctioned was 156.97 MW[3] of solar PV. Average price of successful bids was 91.7 EUR/MWh[4] which is higher than FIT at that time by 1.5 EUR/MWh. This fact may explain a sharp decline of PV installations in Germany, from about 7604 MW in 2012 to about 3304 MW in 2013 and 2006 MW in 2014.

In addition, auction scheme is more precise about quantities to be produced than price-based approaches, since the amount of produced RES-E is stipulated in the contract, and more precise about prices than quantity-based approaches, since the contract also stipulates the prices. Consequently, auction scheme exclude some flaws of price and quantity based approaches.

However, auction scheme will work best if competitive environment is assured, so small players should not be discouraged to participate. Consequently, transaction costs must be minimised. Also, the process must be as transparent as possible in order to exclude room for corruption. A very good guide for designing renewable energy auctions was published by IRENA and CEM in 2015, titled: "Renewable Energy Auctions – A Guide to Design."

This policy is gaining acceptance worldwide, with less than 10 countries with such mechanism in 2005 to some 60 countries in early 2015. In 2014, European Commission released guidelines by which Member States had to switch from FITs to auction mechanism starting from 2017.

[3]IRENA and CEM (2015)

[4]See prev. note

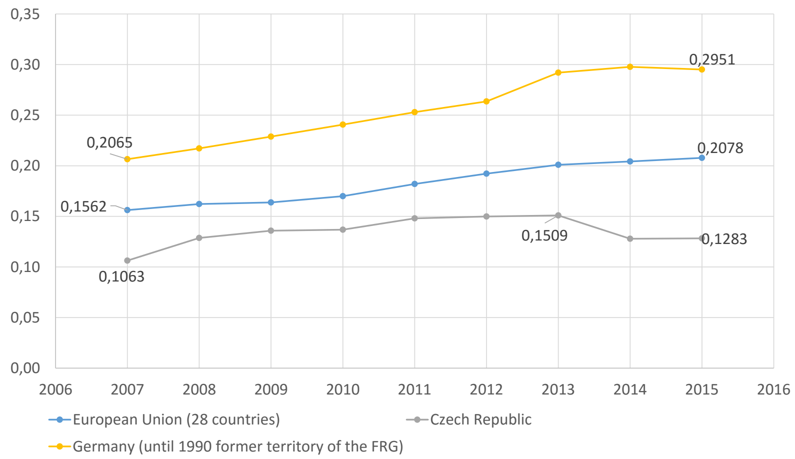
Chapter 3

Problems of Renewables

3.1 Critique of supporting policies in literature

German Renewable Energy Sources Act (EEG) is widely considered as a very successful tool for increasing share of RES in electricity consumption. Nonetheless, this has come with excessive costs for end customers. German household electricity prices went up from 14 EURcent/kWh in 2000 to 29 EURcent/kWh in 2013, see Figure 3.1 for more details about the development of prices for households.

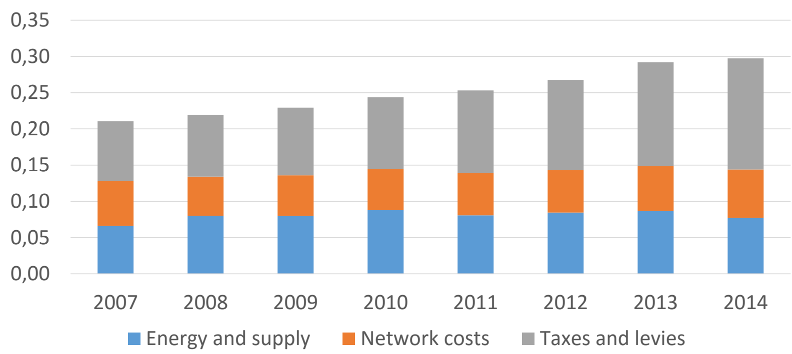
Figure 3.1: Prices for households



Source: Eurostat

Among RES technologies, only large hydropower stations are not dependent on support, which is provided by EEG (Frondel et al., 2009), since hydropower is a very mature technology. End customers through so-called EEG levy pay all additional costs associated with subsidies. In 2000, EEG levy was 0.19 EURcent/kWh and increased to the level of 6.24 EURcent/kWh in 2014. See Figure 3.2 for more details about the price structure of German households. The overall cost of EEG subsidies increased drastically during 2009 – 2014, from about EUR 5 billion in 2009 to some EUR 25 billion in 2014. (Poser et al., 2014).

Figure 3.2: German price structure



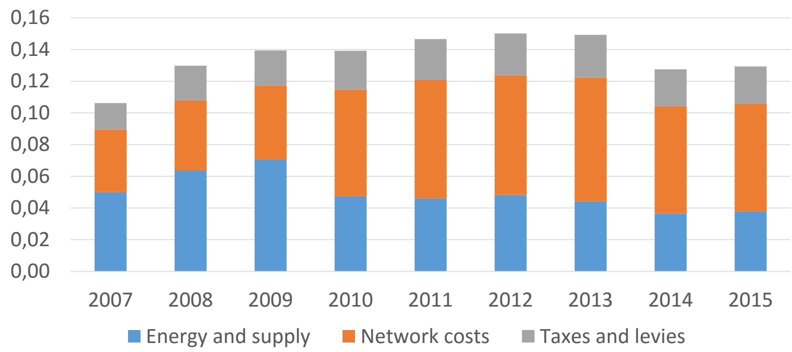
Source: Eurostat

Price structure for Czech households is different. As it can be seen from Figure 3.3, taxes and levies account for moreless same portion since 2008. In fact, it slightly increased from 2.21 EURcent/kWh in 2009 to 2.36 EURcent/kWh in 2015, growth of only 6.8%. Whereas in Germany for the period from 2009 to 2014[1] growth was 64%. However, the surcharge for support of RES went up from 6.7 EUR/MWh in 2010 to 19.8 EUR/MWh in 2014. The development of price structure of Czech households is depicted in Figure 3.3.

From 2001 until 2008, amount of feed-in tariffs in Germany went up from some EUR 1.6 billion to EUR 9 billion. With such large amounts of subsidies, only 211.1 million euros were allocated to R&D in renewable energies by government, this accounts for 3% of the total expenses related to FITs (Frondel et al., 2009). Nonetheless, these support schemes have been very successful in

[1] no data for 2015

Figure 3.3: Czech price structure



Source: Eurostat

aspect of increasing installed capacities of RES. In Germany, photovoltaics, the recipient of highest FITs, increased its capacity from 100 MW in 2000 to 5311 MW in 2008. In the Czech Republic, installed capacity of PV between 2008 and 2010 soared from 39.5 MW to 1959.1 MW. In addition, Prusa et al. (2013) calculated that in 2011 average usage of Czech PV plants was only 1099 hours (12.54% of the total number of hours in the year) and the total cost of PV subsidies was about EUR 972 million and EUR 216 million out of this amount is "the pure dead weight loss". Prusa et al. (2013) define the pure DWL as follows:

> The pure DWL component is a net loss to the economy, because it captures the extent of inefficient electricity production. p_{02} [the pure DWL - *author's note*] is equivalent to an artificial cost which would not exist were it not for the subsidies. This cost appears because money is invested in PV production capacity that is more expensive than other feasible sources.

Feed-in tariffs are usually granted for 20 years, this is a good feature for investors, since they can be assured in long-term support. So even if they would be abolished this year, additional costs will still be paid for 19 years by end customers, if no retrospective legislation will be put in force. While, putting retrospective laws in force is a very bad signal for investors, since they cannot be confident with safety of their investments. In 2010, Czech Republic introduced retroactive legislation in the form of a withholding tax of 26% for photovoltaics with installed capacity of over 30 kW valid for 2011 – 2013. Furthermore, Czech government cancelled previously guaranteed tax-free period of first five years of a project life. The impact was instantaneous, annual installed capacities of PV plummeted from 1494.5 MW in 2010 to 11.9 MW in 2011, 99.2% decrease in just one year. Average annual installed capacities for the period 2011 – 2014 is 27.075 MW, furthermore, in 2014 there was even negative installed capacity, i.e. dismantling of some[2] PV stations. Moreover, such legislative action of the Czech government also indirectly impacted wind sector, in 2011 only 1.1 MW of wind capacity were installed, whereas in 2010 24.6 MW of wind capacity were installed, 95.5% decrease in just one year. Hydropower also was affected, in 2011 1.5 MW of hydropower capacity were dismantled, while in 2010 19.6 MW of hydropower capacity were installed, i.e. more than 100% decrease. Of course we cannot claim, that PV, wind and hydropower sectors declines were caused solely by the Czech legislative action. For instance, additional reason for PV sector decline is a stoppage of connections into the grid for new PV plants in 2010, this problem is more explained in section 3.1.1. Nevertheless, we see that a large drop in installed capacities occurred next year after Czech government introduced such an unpopular legislation.

In Germany, FITs for wind farms put in operation in 2003 are expected to be lower than prices for electricity in 2022 (Frondel et al., 2009). Therefore, it will take 19 years for wind farms to be competitive without subsidies. It should be mentioned that onshore wind is considered as moreless mature technology.

Furthermore, technology specific feed-in tariffs reduce competition within RES. If FITs would have been same for all types of RES, we would not be able to claim that PV installations would had resulted in same capacities as now. Though in Germany, installations of PV plant capacities exceed that ones of biomass, biomass has generated much more energy than solar PV plants. So if subsidies would be the same, it probably would be more economically reasonable to invest into biomass sector rather than into PV sector. Prusa et al. (2013) found out that in the Czech Republic, for PV plants to be non-loss making either prices have to go up seven times or costs have to be reduced seven times.

Whilst prices for end customers increased, wholesale prices have decreased. In Germany, base load prices plummeted from 90-95 EUR/MWh in 2008 to 37 EUR/MWh in 2013. This created financial problems for utilities that operated thermal power plants. German utilities companies stocks went down by almost

[2] 65 MW

45 percent from 2010 to 2014 and credit ratings are lowered for them from A to A- or in case of RWE even to BBB+ (Poser et al., 2014).

Frondel et al. (2010) suggest instead of excessive subsidies for RES to invest more in R&D. Now producers of RES-E are induced to be more cost efficient via degressive rates of FITs.

Likewise, Menanteau et al. (2003) suggest introduction of "optimum environmental tax". So consumers would be induced to choose between efficient use of energy from conventional resources or use energy from RES without such tax. So if the cost of pollution and other environmental damage from conventional production of energy can be properly estimated such Pigovian tax can be introduced. This would correct the market imperfections (Menanteau et al., 2003). We know similar tax as tax on CO2 emissions.

3.1.1 Problems of integrating renewable energy into the grid

One more problem of renewables is grid connection. Producers of RES-E are entitled to have a priority access into the grid. But locations of some plants are far away from the grid, for instance offshore wind farms in Germany. So expansion of transmission grids needs large investments. Investment costs for Germany are estimated to be approximately EUR 40 billion (Poser et al., 2014) over the decade. There is the "Grid Development Plan" in Germany, which encompasses development of infrastructure and connection of north offshore wind plants with southern regions. In 2012, energy transition induced four German TSOs to spend EUR 1.15 billion on network infrastructure.

In the Czech Republic, the most favourable locations for wind farms are along the German and Polish borders, as well as Slovakian border and also in the Moravian highlands. Accordingly, they are remote from the biggest consumption centers such as Prague, Ostrava and Brno. Until 2023, Czech TSO is going to invest into expansion of the grid CZK 60-70 billion[3] (EUR 2.2 - 2.59 billion; exchange rate is 27) this is the biggest investment in the history[4] of the country. However, this expansion is planned not only due to increasing installed capacities of RES but mainly because of increasing capacity of nuclear power. In contrast with Germany, Czech Republic is not planning to abandon nuclear power.

In the Czech Republic, in February 2010 due to technical reasons Czech

[3] Jirous et al., 2011
[4] as of 2011.

TSO requested stoppage of connections into the grid for new PV plants. Czech TSO stated that excessive amount of new PV plants can threaten security of the grid.

For grid operators there are also so-called grid balancing costs. Such costs arise due to intermittent character of some types of RES. Wind and solar technologies are dependent on weather, so when there is no wind wind farms do not generate electricity and when there is a cloudy sky PV plants do not generate electricity. Thus, grid operators must balance out electricity capacities in the grid in order to prevent stoppages of electricity supply and security of the grid. Next section discusses intermittency problem more detailed.

3.1.2 Intermittent character of renewable energy

Many proponents of RES say that RES will decrease dependency from depleting fossil fuels. However, RES tend to have intermittent character. For example, onshore wind farm with installed capacity of 100 MW will produce only 20-35%[5] of electricity that it would have produced if suitable weather conditions were holding all the year round – this is known as the capacity factor. For solar PV plants, the capacity factor is between 10-20%[6].In order to save customers from blackouts backup energy systems must be in place. In Germany, on January 5, 2012 solar and wind combined production was 500 GWh, maximum for that year; and minimum was on December 19, 2012 with combined production of only 30 GWh. Therefore, large backup capacities of thermal power plants must be in place (Poser et al., 2014).

There are different ways to tackle the problem of intermittency, the major ones are:

- Use of fossil fuels, so at times when RES-E producers are unable to meet the demand, conventional plants start to produce electricity. Maintenance of such systems is costly. For Germany, amount of EUR 590 million in 2006 was calculated by Erdmann (2008). The use of fossil fuels is relatively easy and cheap only in case of long-term balancing (i.e. days or week notice).

- Transmission of surplus from one location to another, this requires good interconnection between locations. This goes back to the development of

[5]FS-UNEP, 2016

[6]See prev. note

the grid and also may require good collaboration between the states. In addition, it will increase the grid balancing costs.

- Demand response, so when RES expected to produce low volume of electricity, large industrial and commercial customers are paid by the grid operator to lower their consumption of electricity by switching off machines and/or air conditioning etc. The amount of payment must be properly calculated, nevertheless this method is costly and difficult to implement. This method is relatively easy to implement in medium-term notice (i.e. hours).

- Energy storage, surplus of produced RES-E is stored and when RES-E producer cannot meet the demand stored electricity is fed into the grid. Probably the best option in short notice (i.e. seconds to minutes).

The latter option is promising because prices for batteries have been falling. For example, prices of electric vehicle batteries are steadily decreasing. The average cost per kWh fell from some 1000 $ in 2010 (EUR 757.57, exchange rate is 1.32, which is average monthly rate for 2010) to some 390 $[7] in 2015 (EUR 354.55, exchange rate is 1.10, which is average monthly rate for 2010). The decrease is caused by technological improvements as well as economies of scale. This is also driven by increasing demand for electric vehicles. There are two types of storage: so-called "behind the meter" and the grid-scale storage.

Behind the meter storages are located inside the buildings and reserved for self use. Germany has a subsidy programme for small-scale PV installations with storage effective from 2013. By the end of September 2015, 27 000 storage systems were sold with capacity of 136 MWh[8].

Grid-scale battery storages are of much larger capacities and located close to wind farms or solar plants. For instance, in Germany 5 MWh storage system was put in operation for utility which operates a large share of wind energy. In 2015, worldwide 1220 MW[9] of grid-scale projects were announced.

Nonetheless, the storage systems increase the costs of RES-E. In 2015, German levelised cost of electricity for onshore wind farm with storage of 50% of total installed capacity is 120 $/MWh[10] (EUR 109.09, exchange rate is 1.10), which is 48% higher than without storage capacity. For PV plants such cost

[7]See prev. note
[8]See prev. note
[9]See prev. note
[10]See prev. note

is 198 \$/MWh[11] (EUR 180, exchange rate is 1.10), which is 85% higher than without storage. Consequently, we see that storage systems increase the costs substantially, yet these costs tend to decrease, since prices for batteries decrease and overall development of storage technology is promising.

In addition, wholesale prices have become dependent on weather conditions. Wholesale prices go down when the sun shines and the wind is strong and go up when no wind and no sun but high demand for power remains. Therefore, price forecasts for futures have become more subtle and complicated.

3.1.3 Reduced CO2 emissions

Prices of CO2 emission certificates, which are traded on European Emissions Trading System (ETS), have never been above 30 EUR/tonne of CO2. In 2008, calculated cost of abatement one tonne of CO2 emission by PV in Germany was 716 euros and by wind energy was 54 euros (Frondel et al., 2009). Therefore, from economic point of view it is much more beneficial to buy certificates than subsidize renewable energies.

Nevertheless, in 2009, about 340 million metric tonnes of CO2 emissions were saved by the use of RES in EU. Taking the price of 15 EUR/tonne of CO2 in 2009, savings will result in EUR 51 billion for 2009 year alone (Poser et al., 2014).

In order to see correlation between change in RES share in gross final energy consumption and greenhouse gas (hereinafter GHG) abatement for Germany we will run the following regressions[12]

$$\begin{aligned} GHGE &= \beta_0 + \beta_1 RESE \\ GHGHC &= \beta_0 + \beta_1 RESHC \\ GHGT &= \beta_0 + \beta_1 REST \end{aligned}$$

where, $GHGE = GHGE_t - GHGE_{t-1}$, i.e. yearly change in amount of GHG abatement induced by change in RES-E share in gross final electricity consumption; and $RESE = RESE_t - RESE_{t-1}$, i.e. yearly change of RES-E share in gross final electricity consumption. Analogously, other two regressions should be read. Likewise, all three regressions were tested for heteroskedas-

[11]See prev. note
[12]Stata outputs for all regressions can be found in Appendix A.

ticity (hettest), normality (swilk) and specification test for omitted variables (ovtest) results can be found in Appendix A in notes under the relevant table.

No regressions were run for the Czech Republic due to lack of data.

Figure 3.4: GHG abatement by different types of RES

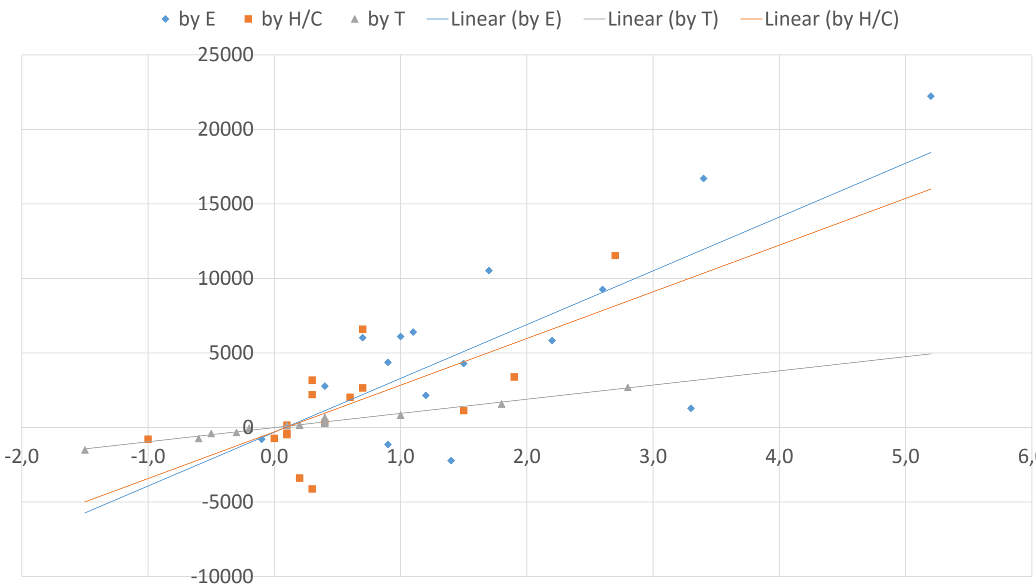


Figure 3.4 is a scatter plot for all three regressions. Y-axis is measured in tonnes of CO2 equivalent and X-axis is measured in percentage points. Regression of GHG abatement by RES-E resulted in R-squared of 0.5653, i.e. 56.53% of variability in dependent variable is explained by the independent one. Likewise, equation of the regression – a blue line – is:

$$\widehat{GHGE} = \underset{(1820.415)}{-317.18} + \underset{(845.79)}{3609.046} RESE$$

Coefficient is statistically significant even at 1% significance level. Thus, one percent increase of RES-E share in gross final electricity consumption results in abatement of 3609.046 tonnes of CO2 equivalent. Constant in this regression is statistically insignificant.

Regression of GHG abatement by RES-H/C has R-squared of 0.5113. Equation of the regression line – an orange line – is:

$$\widehat{GHGHC} = \underset{(818.14)}{-290.5662} + \underset{(818.3969)}{3132.254} RESHC$$

Constant is statistically insignificant, whereas coefficient is statistically significant even at 1% significance level. Therefore, when RES-H/C share in final energy consumption in heating and cooling is increased by 1%, GHG abatement increases by 3132.254 tonnes of CO2 equivalent.

Regression of GHG abatement by RES-T has R-squared of 0.9851, which is almost perfect correlation. Equation of the regression line – a grey line – is:

$$\widehat{GHGT} = \underset{(31.26)}{-6.637} + \underset{(31.3)}{951.2398} REST$$

Here constant is also statistically insignificant and coefficient is statistically significant even 1% significance level. Thus, 1% increase in RES-T share energy consumption in transport increases GHG abatement by 951.239 tonnes of CO2 equivalent.

Having these results and estimations of RES shares from Table 2.2 we can estimate the amount of GHG abatement in 2020 by multiplication of relevant coefficients with estimated shares of relevant RES. Thereby, we have the following estimations:

$$\begin{aligned} RES - E_{2020}\text{x}coef.RESE &= 139309.2 \\ RES - H/C_{2020}\text{x}coef.RESHC &= 48549.94 \\ RES - T_{2020}\text{x}coef.REST &= 12556.37 \end{aligned}$$

All estimations are measured in tonnes of CO2 equivalent. Thus, we have that in 2020 year alone total estimated GHG abatement is 200 415.5 thousand tonnes of CO2 equivalent, according to German NREAP 215 million tonnes of CO2 equivalent will be prevented by 2020, thus there is less than 7% discrepancy between my estimations and German NREAP estimations. Taking into account that prices of certificates on ETS should increase, savings in money equivalent will be significant. If we take current price[13] of EU Emission Allowance – 6.05 EUR per tonne of CO2 equivalent, we can estimate that savings in 2020 year alone will be 1.213 billion EUR. However, these estimation is assuming that prices will remain at its current level, whereas they must go up, since the number of the certificates will gradually go down. This estimation is conducted in order to show you the size effect of GHG abatement.

[13] 6/5/2016 13:14

Chapter 4

Analysis of dependence between installed capacity and feed-in tariffs

4.1 Model description

We are going to analyse dependence between feed-in tariffs and installed capacity of each type of RES-E in Germany and the Czech Republic via linear regression. Firstly, we will use simple linear regression, our dependent variable will be installed capacity in year t, MW_t, and independent variable will be FIT in year t, FIT_t. Thus, the equation will be:

$$MW_t = \beta_0 + \beta_1 FIT_t$$

Then for some types of RES we will add polynomial of second order and in two cases polynomial of third order, in case of Czech solar RES we will add a polynomial of fourth order and a dummy, reasoning will be explained later. Therefore the equations will be:

$$MW_t = \beta_0 + \beta_1 FIT_t^2 + \beta_2 FIT_t$$
$$MW_t = \beta_0 + \beta_1 FIT_t^3 + \beta_2 FIT_t^2 + \beta_3 FIT_t$$
$$MW_t = \beta_0 + \beta_1 FIT_t^4 + \beta_2 FIT_t^3 + \beta_3 FIT_t^2 + \beta_4 FIT_t + \beta_5 D$$

All successful regressions (i.e. p-value of F-test is lower than 0.05 or in some cases lower than 0.1) were tested for heteroskedasticity (hettest), normality (swilk) and specification test for omitted variables (ovtest) results can be found in Appendix A in notes under the relevant table.

For Germany data will be taken between years 2000 and 2015. However, if value of FIT_t for some t is zero, then this year is omitted. There are such cases in landfill, sewage and mine gas RES, where FITs were introduced in 2004, in geothermal RES, where FITs were introduced also in 2004, and in offshore wind RES, where FITs were introduced in 2009. The data for Germany is taken from Federal Ministry for Economic Affairs and Energy. It should be mentioned that each technology-specific average FIT for a given year will be used as FIT_t.

For the Czech Republic data will be taken for 2002 – 2015 period. No restrictions on value of FIT_t are imposed. Nevertheless, for the Czech Republic we managed to collect much less data than for Germany. We could not find data about installations of biomass and biogas[1] RES. The data for the Czech Republic is taken from the Energy Regulatory Office.

4.2 Outcomes of the model

Regression for German hydropower resulted in statistically insignificant coefficient of FIT, p-value of the coefficient is 0.543. In addition, R-squared is only 0.0271, which means that only 2.71% of variability in dependent variable is explained by the independent one. Finally, regression itself is insignificant, since p-value of the F-test is 0.5426. This is caused by the fact that sites for such RES technology are scarce, since can be located only on rivers. Therefore, there is no relation between the size of FIT and installation amounts. Average annual growth rate of installed capacity for the period of 2001 – 2015 is 0.99%. It should be noted, that hydropower is the most mature type of RES among all, since it has been developing for decades.

Regression for Czech hydropower also resulted in statistically insignificant coefficient of FIT, p-value of the coefficient is 0.585. R-squared of the regression is only 0.0527. This is caused by the same reasons as in German case.

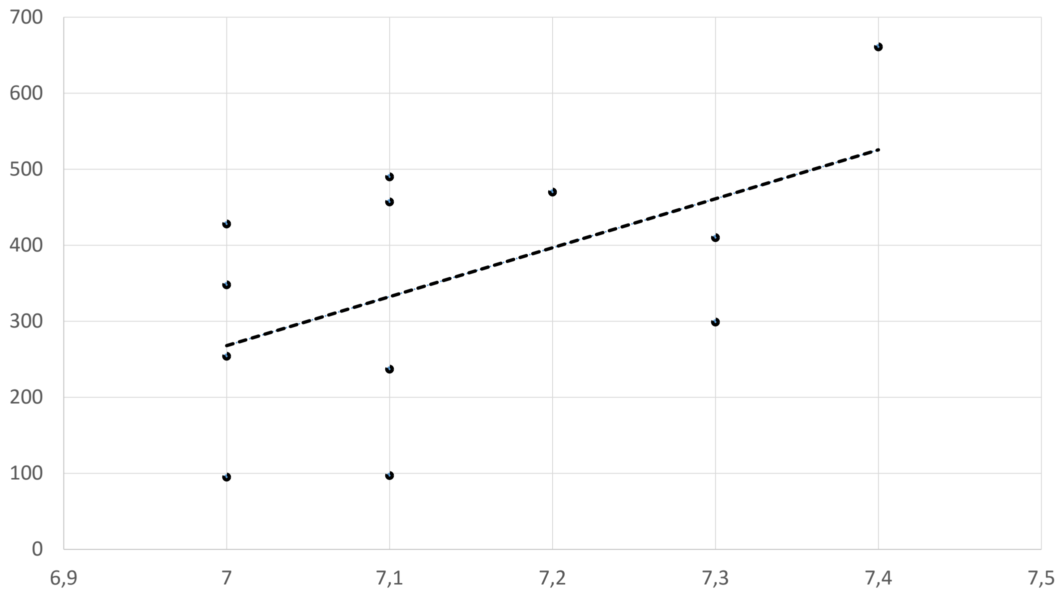
Figure 4.1 is a scatter plot for German landfill, sewage and mine gas RES. Y-axis is the amount of annual installed capacity of this RES in MW. X-axis is a feed-in tariff in EURcent/kWh. Equation of the line is:

$$\widehat{MW} = \underset{(2325.79)}{-4239} + \underset{(325.99)}{643.87}FIT$$

Thus, one cent of FIT corresponds to 643.87 MW of installed capacity. For

[1] For biogas we managed to find such data for 2006 and 2007, but then in ERO reports such data is missing.

Figure 4.1: German landfill, sewage and mine gas



Source: BMWi and own computations

instance, if in year t+1 FIT will be increased by one cent, then installed capacity will be increased by 643.87 MW in comparison to year t. p-value of the coefficient is 0.076[2], i.e. coefficient is statistically significant at 10% significance level. Likewise, overall significance of the regression is achieved only at 10% significance level, since p-value of the F-test is 0.0765. In addition, so far maximum change of FIT was 0.2 cent, increase in 2011 from 7.2 to 7.4 and decrease in 2013 from 7.3 to 7.1. R-squared of this equation is 0.2806, i.e. independent variable explains 28.06% of variability of dependent variable. Though, average growth rate of FIT between 2005 and 2015 is only 0.14%, average annual growth rate of installed capacity is 20.97%.

No regression was run for the Czech Republic due to lack of data.

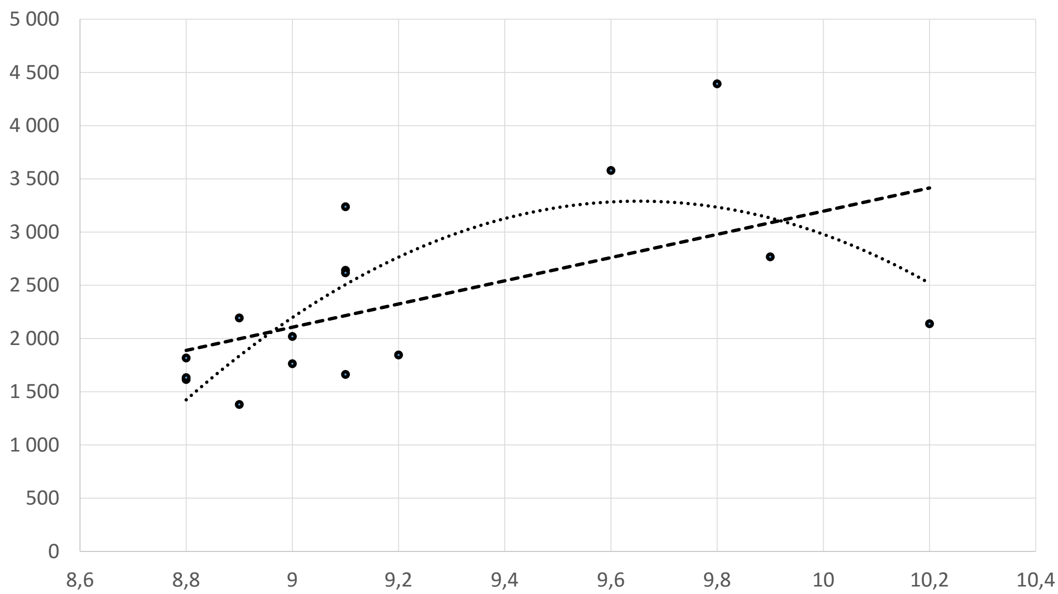
Geothermal type of RES started to develop in Germany in 2007, when the first 2 MW of this type of RES were installed. Average growth rate of installed capacity is 55%, nonetheless there were years with no increase at all and years such as 2012, when 13 MW were added, resulting in 260% increase in comparison to 2011. Regression resulted in statistically insignificant coefficient and constant, with p-values 0.34 and 0.55 respectively. Moreover, overall regression is insignificant, p-value of the F-test is 0.3396. This is caused by scarcity of this type of RES, i.e. special site needed to be found in order to generate

[2]For full Stata output of all regressions see Appendix A.

geothermal energy. Therefore, feed-in tariffs do not impact amount of installed capacity of this type of RES.

No regression was run for the Czech Republic due to lack of data.

Figure 4.2: German onshore wind



Source: BMWi and own computations

Figure 4.2 is a scatter plot for German onshore wind RES. Y-axis and X-axis are same as in Figure 4.1. Equation of the dashed line is

$$\widehat{MW} = \underset{(3906.02)}{-7703.76} + \underset{(423.84)}{1090}\, FIT$$

Therefore, one cent of FIT corresponds to 1090 MW of installed capacity. For instance, if in year t+1 FIT will be increased by one cent, then installed capacity in year t+1 will be increased by 1090 MW in comparison to year t. R-squared of this equation is 0.3208, i.e. independent variable explains 32.08% of variability of dependent variable. p-value of independent variable is 0.022, i.e. it is statistically significant at 5% significance level, whereas, p-value of constant is 0.069, i.e. it is not statistically significant at 5% significance level, however at 10% significance level it is statistically significant. But, Breusch-Pagan test for heteroskedasticity yields that there is a constant variance[3]. Nevertheless, when we add in the model a polynomial of the second order, Breusch-Pagan test for heteroskedasticity rejects null hypothesis, which is constant variance of dependent variable fitted values. Likewise, R-squared increases to the level of 0.5525,

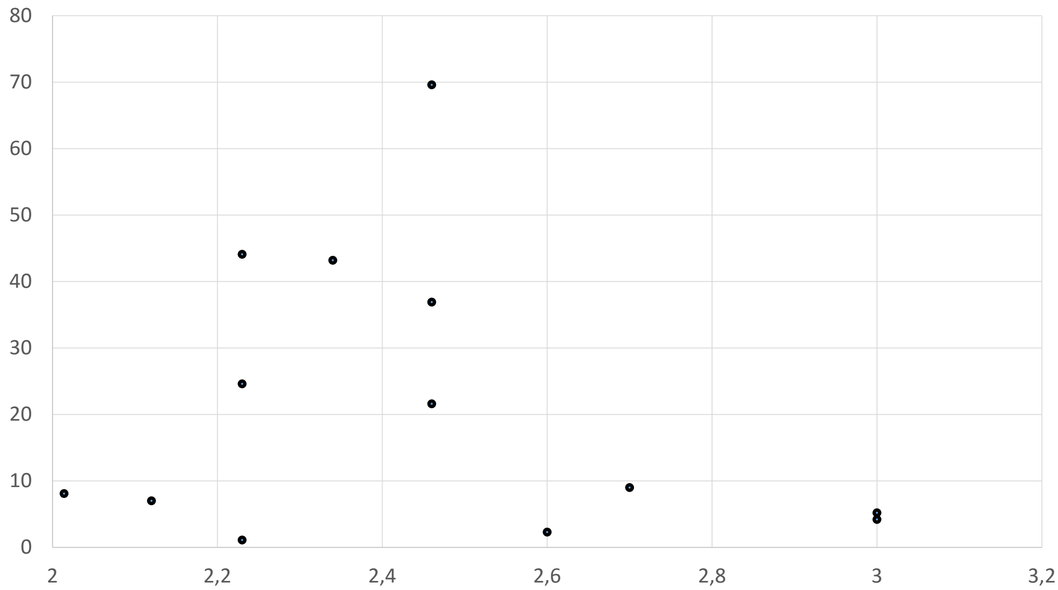
[3] See Appendix A for p-value of other tests.

all coefficients and constant are statistically significant at 5% significance level. The equation of this model – dotted line – is:

$$\widehat{MW} = \underset{(991.01)}{-2570.459}FIT^2 + \underset{(18714.03)}{49620.89}FIT - \underset{(88148.72)}{236183.6}$$

By calculating the maximum of this parabola we find the optimum FIT for onshore wind RES, i.e. under this FIT the maximum annual installed capacity is anticipated. The optimum FIT is 9.65 EURcent/kWh. Therefore, higher FITs are inefficient, since they result in lower installed capacities at higher expenses. Likewise, FITs below 8.52 will result in negative installed capacities. Therefore, FITs should be set inside (8.52;9.65] interval. In addition, average growth rate of FIT is only 0.40% for the period of 2001 – 2015, average installed capacity growth rate is 14.16%.

Figure 4.3: Czech wind

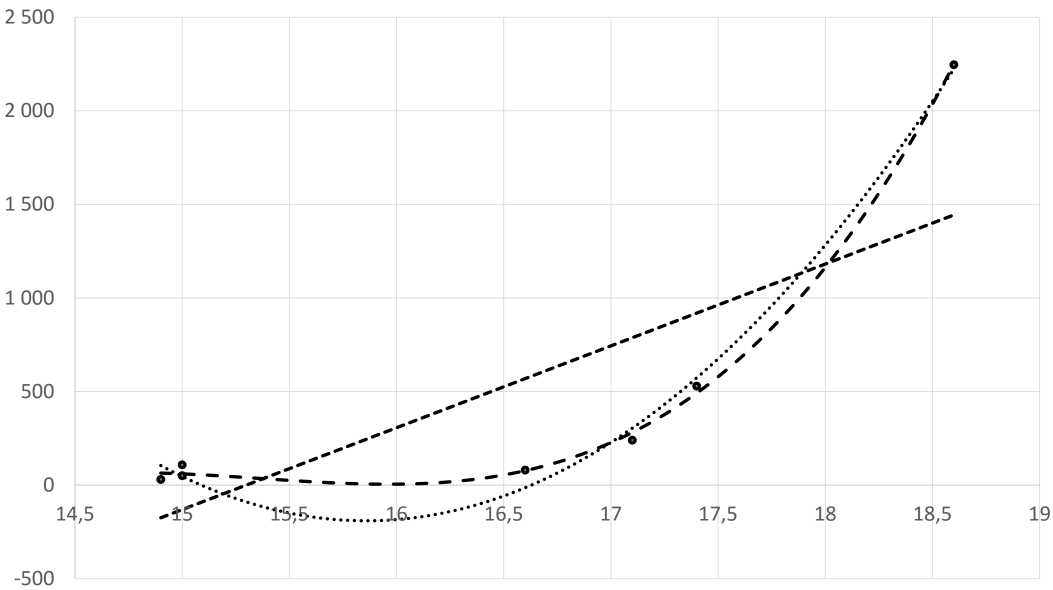


Source: ERO

Figure 4.3 is a scatterplot for Czech wind RES. Y-axis is in MW of installed capacity and X-axis is a feed-in tariff in CZK/kWh. I have run various regressions: simple ones, with polynomials of the second, third and even fourth orders. No regression was successful. It is seen from Figure 4.3 that data is very dispersed, thus very difficult to draw a line which would approximately match the pattern. In all regressions, overall p-values were greater than 0.1706. Thus, we can conclude that wind installations are independent from FITs.

Figure 4.4 is a scatter plot for offshore wind RES in Germany. Y-axis and

Figure 4.4: German offshore wind



Source: BMWi and own computations

X-axis are same as in Figure 4.1. Equation of the dashed line is

$$\widehat{MW} = \underset{(2616.775)}{-6702.93} + \underset{(159.46)}{438.46} FIT_t$$

Hence, one cent of FIT corresponds to 438.46 MW of installed capacity. For instance, if in year t+1 FIT will be increased by one cent, then installed capacity will be increased by 438.46 MW in comparison to year t. R-squared of this equation is 0.6019, i.e. independent variable explains 60.19% of variability of dependent variable. Independent variable is statistically significant at 5% significance level, p-value of constant is 0.051, i.e. constant is almost statistically significant at 5% significance level. Yet, Ramsey RESET test concludes that we have omitted variables[4]. Accordingly, when we add in the model a polynomial of second order, R-squared of the model increases to the level of 0.9910, i.e. model explains 99.1% of variability in the dependent variable. In addition, all coefficients and constant are statistically significant even at 1% significance level. The equation of the model – dotted line – is:

$$\widehat{MW} = \underset{(26.86775)}{353.0522} FIT^2 - \underset{(886.7051)}{11207.84} FIT + \underset{(7275.592)}{88725.89}$$

The minimum corresponds to the point where derivative changes its sign, i.e.

[4]See Appendix A for p-values of tests.

negative marginal returns change to increasing marginal returns. The minimum here is 15.8727, parabola at this point is below zero, i.e. when FIT is set at 15.8727 annual installed capacity will be negative. So producers of RES will dismantle their wind farms. Actually, parabola is negative when values of FIT are inside [15.0764;16.6691] interval. Therefore, FITs should not be set inside this interval. However, such model implies that FIT set at 0 will result in 88725.89 MW of installed capacity, which is barely can make sense. In order to exclude this shortcoming of the model, we add a polynomial of third order, and now the model – wide dashed line – is:

$$\widehat{MW} = \underset{(24.15052)}{9}\quad 9.41284FIT^3 - \underset{(1216.998)}{4656.334}FIT^2 + \underset{(20371.35)}{72632.58}FIT - \underset{(113251.5)}{377268}$$

All coefficients and constant are statistically significant at 5% significance level. R-squared increased a little bit to the level of 0.9986. There are two points where derivative is zero: 15.1436 and 16.082. Inside the interval of these two values marginal returns are negative. Therefore it is inefficient to set FITs inside this interval. In addition, FITs set below 14.5612 result in negative installed capacities. Accordingly, FITs should be set inside the intervals (14.5612;15.1436] and $(16.5519; +\infty)$. We excluded interval (16.082;16.5519) because FITs set inside [14.6736;15.1436] interval result in same installed capacities but with lower FITs.

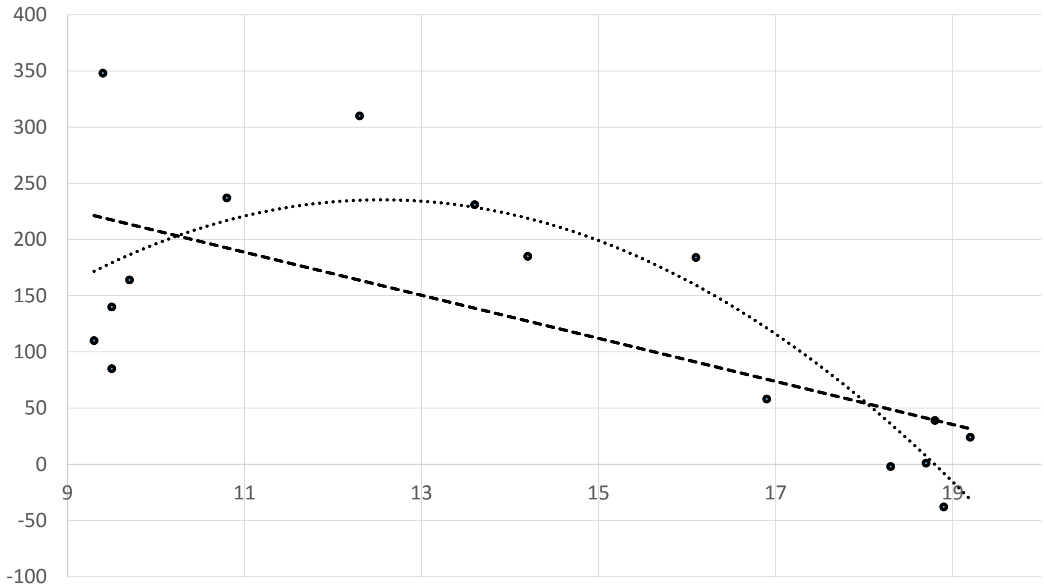
First offshore wind farms in Germany were installed in 2009, with 30 MW. Ever since, the average annual growth rate of installed capacity is 126%. Offshore wind projects are very expensive, since they have excessive initial investment costs. And the project makes sense only if it is of bigger scale, that is why we see such big growth rates of installed capacities. This type of RES showed incredible growth, with only 30 MW installed in 2009, 3283 MW were installed in 2015 alone. Growth of more than 10 000 % in 6 years.

Figure 4.5 is a scatter plot for biomass RES. Y-axis and X-axis are same as in Figure 4.1. Equation of the dotted line is

$$\widehat{MW} = \underset{(82.6653)}{399.44} - \underset{(5.66)}{19.16}FIT_t$$

That is, one cent of FIT corresponds to decrease of 19.16 MW of installed capacity. For instance, if in year t+1 FIT will be increased by one cent, then installed capacity will be decreased by 19.16 MW in comparison to year t. Constant and independent variables are statistically significant at 5% significance

Figure 4.5: German biomass



Source: BMWi and own computations

level. R-squared of this equation is 0.4501, i.e. independent variable explains 45.01% of variability of dependent variable. Likewise, when we add a polynomial of second order R-squared increases to the level of 0.6808. Coefficients remain statistically significant at 5% significance level, but p-value of constant is 0.075, thus constant is statistically significant only at 10% significance level. The equation of the model – dotted line – is:

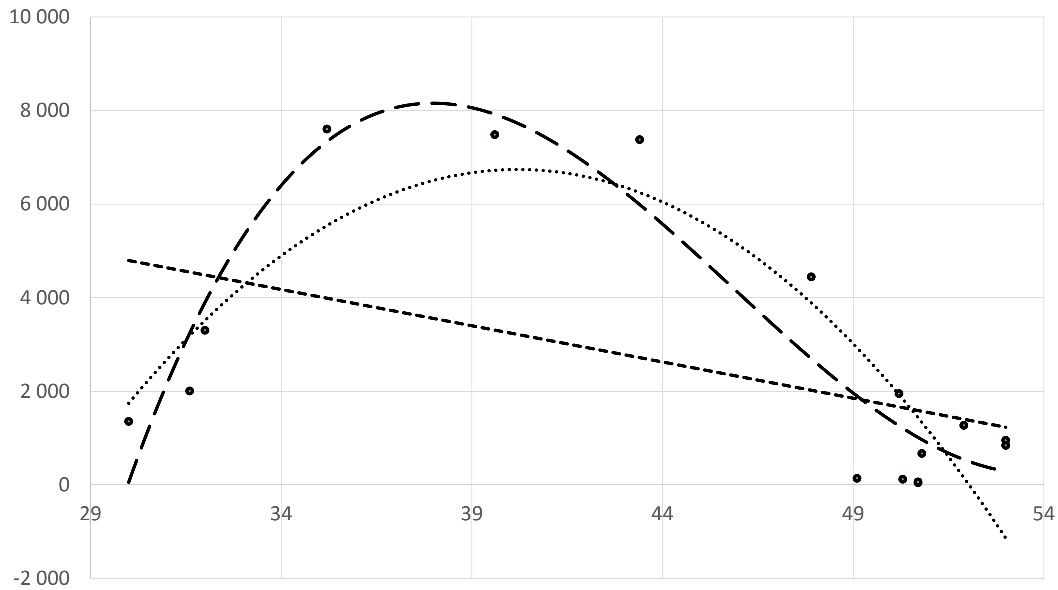
$$\widehat{MW} = \underset{(1.966)}{-6.027}FIT^2 + \underset{(55.77982)}{151.2494}FIT - \underset{(368.9966)}{713.6272}$$

The maximum of the parabola is the optimum FIT, i.e. maximum annual installed capacity is achieved under this FIT. The maximum is at 12.5476, consequently FITs higher than 12.5476 are inefficient, since they will result in lower installed capacities at higher costs. In addition, FITs set below 6.29957 will result in negative installed capacities. Therefore, FITs should be set inside (6.29957;12.5476] interval. Average growth rate of FIT between 2001 and 2015 is 5% and average annual growth rate of installed capacity is 16%. Nevertheless, in recent years the growth slowed down to average of 0.62%[5]. The boom of installations of this type of RES was between 2001 and 2006 with average annual growth rate of 33%.

No regression was run for the Czech Republic due to lack of data.

[5]Average annual growth rate between 2010 and 2015.

Figure 4.6: German solar energy



Source: BMWi and own computations

Figure 4.6 is a scatter plot for solar RES in Germany. Y-axis and X-axis are same as in Figure 4.1. Equation of the line is

$$\widehat{MW} = \underset{(3542.484)}{9441.76} - \underset{(77.53)}{154.9} FIT_t$$

Constant is statistically significant at 5% significance level and independent variable is statistically significant only at 10% significance level as well as whole regression is significant only at 10% significance level. R-squared of this equation is 0.2219, i.e. independent variable explains 22.19% of variability of dependent variable. With one cent increase in FIT, installed capacity will decrease by 154.9 MW. But, Ramsey RESET test concludes that we have omitted variables. Thence, we add a polynomial of second order. All coefficients and constant become statistically significant even at 1% significance level and regression is overall significant even at 1% significance level. R-squared increases to the level of 0.7148. The equation of the model – dotted line – is:

$$\widehat{MW} = \underset{(10.138)}{-48.062} FIT^2 + \underset{(849.1176)}{3863.828} FIT - \underset{(17096.32)}{70916.21}$$

The optimum FIT for this model is where parabola has its maximum. The maximum is at 40.1963, consequently, FITs higher than 40.1963 are inefficient. Furthermore, FITs set below 28.3546 result in negative installed capacities.

Therefore, FITs should be set inside (28.3546;40.1963] interval. Yet, Ramsey RESET test still concludes that we have omitted variables. Thus, we add polynomial of third order and Ramsey RESET test does not conclude that we have omitted variables. It slightly changes our intervals. Likewise, R-squared increases to the level of 0.8531, all coefficients and constant remain statistically significant at 1% significance level. The equation of the model – wide dashed line – is:

$$\widehat{MW} = \underset{(1.19885)}{4.0298}FIT^3 - \underset{(150.8367)}{554.4399}FIT^2 + \underset{(6223.685)}{24675.01}FIT - \underset{(84994.61)}{350005}$$

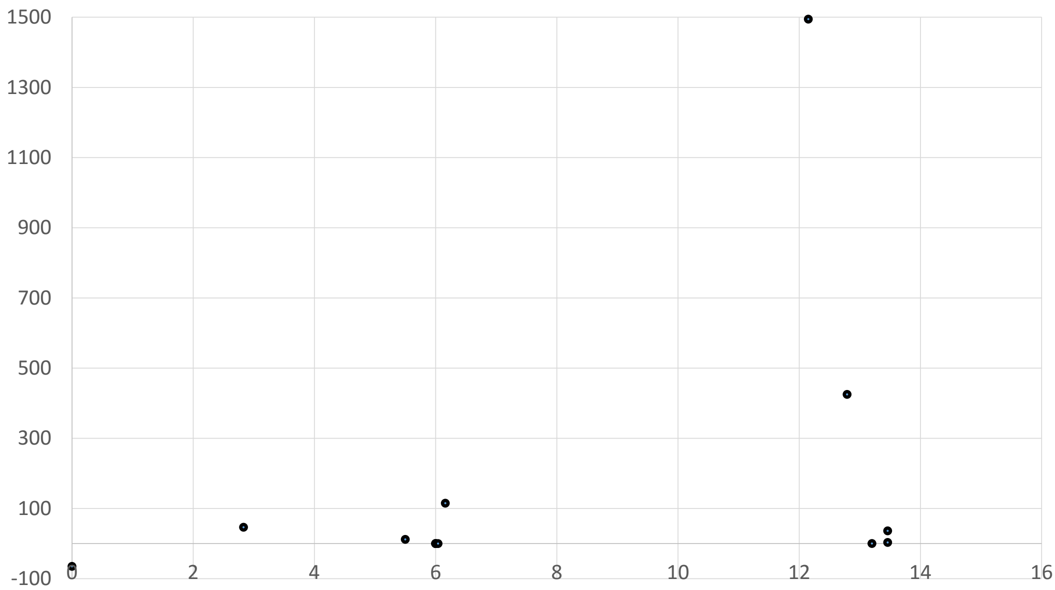
There are two points where derivative is zero: 37.9719 and 53.7514. Inside the interval of these values marginal returns are negative, thus, it is inefficient to set FIT between 37.9719 and 53.7514. In addition, FITs set below 29.9764 will result in negative installed capacities. Therefore, FITs should be set inside the following intervals: (29.9764;37.9719] and $(61.6409; +\infty)$. We excluded interval (53.7514; 61.6409), since values inside [30.0824;37.9719] result in the same installed capacities but at lower FITs. This is the only type of RES for which average FIT has been steadily decreasing since 2006, average decrease rate of 5% between years 2006 and 2015. Nonetheless, average annual installed capacity growth rate for the same period is 16%, with boom in 2009 with 128% annual growth rate. Moreover, now there are 3 consecutive years of negative annual growth rates of installed capacity.

Figure 4.7 is a scatter plot for Czech solar energy. Y-axis and X-axis are same as in Figure 4.3. As it has already been written, in 2010 Czech government introduced a retroactive legislation. Therefore, data after 2010 is very biased. Moreover, in 2010 there was an unexpected boom of photovoltaic installations, which led to stoppage of connections into the grid for new PV installations. That is why, I added a dummy variable "D", which was equal 1 only for 2010 year and 0 for all others years. Only after adding polynomial of fourth order regression was moreless successful. Ramsey RESET test still concluded that there is an omitted variable, though at 4% significance level did not. Breusch-Pagan test for heteroskedasticity did not detect any heteroskedasticity. Regression equation is:

$$\widehat{MW} = \underset{(0.1704983)}{-0.698}\ FIT^4 + \underset{(4.298)}{16.12}FIT^3 - \underset{(35.039)}{107.27}FIT^2 + \underset{(101.4919)}{228.829}FIT + \underset{(137.984)}{913.9}\ D - \underset{(74.32)}{64.49}$$

Constant here is statistically insignificant. Function for FITs has three val-

Figure 4.7: Czech solar energy



Source: ERO

ues where derivatives are zero: 1.57; 4.72; 11.026. Inside (1.57;4.72) interval marginal returns are negative, i.e. it is inefficient to set FITs inside this interval. Inside [4.72;11.026) marginal returns are positive. However, FITs should be set inside the following intervals: (0;1.57] and (6.64;11.026]. We excluded [4.72;6.64] interval because FITs set inside [0.1858;1.57] result in same installed capacities.

Table 4.1: Summary of optimal FITs

Type of RES	**Interval for optimum FITs**
German onshore wind	(8.52; 9.65]
German offshore wind	(14.56; 15.14] and (16.55; $+\infty$)
German biomass	(6.29; 12.55]
German solar	(29.98; 37.97] and (61.64; $+\infty$)
Czech solar	(0; 1.57] and (6.64; 11.03]*

Note: for Czech solar intervals include shortages explained before.

Table 4.1 summarizes all found optimum intervals for feed-in tariffs. We did not find optimum intervals for FITs in cases of: hydro RES of both countries, landfill,sewage and mine gas RES of both countries, Czech wind RES and Czech biomass. Moreover, optimum interval of FITs for Czech solar includes some shortages explained before. Therefore, we have optimum intervals for FITs in 5 cases. Thereby, we believe that if feed-in tariff scheme to be continued and governments want to maximize their installed capacities of RES, they should set feed-in tariffs inside these intervals. For Germany, FITs are measured in euros and for the Czech Republic FITs are measured in Czech korunas.

Chapter 5

Conclusion

The main purpose of this thesis was to determine what are the growth opportunities of renewable energy and how renewable energy is financed in the Czech Republic and Germany.

After reviewing German and Czech NREAPs we ascertained that support for renewable energy is mainly covered by end-customers. End-customers of both countries have additional costs related to support of RES included in their bills. Additional costs related to RES include: feed-in tariffs and other financial types of support, grid development costs and grid balancing costs. All these costs are firstly borne by TSOs and DSOs but then they are passed onto end-customers. However, not all additional costs are borne by end-customers, in the Czech Republic, there is a subsidy, which covers the costs of market operators associated with FITs. In addition, RES producers have some tax benefits. This support resulted in significant increase of installed capacities in all types of RES excluding hydro, since it has already been very developed. However, since feed-in tariff scheme is regarded as a very costly method and moreover, European Commission has approved the removal of all feed-in tariff schemes from 2017, Germany has already started to shift towards auction scheme.

In Chapter 4, I analyse the dependence between annual installed capacities of RES and respective feed-in tariffs. We took the empirical data of annual installed capacities and regressed it on respective FITs and/or their polynomials. The analysis resulted in optimum intervals for some types of RES, they are summarised in Table 4.1. We could not collect most of the data for the Czech Republic, since the Energy Regulatory Office of the Czech Republic does not publish the time series for RES, unlike Germany, which publishes a comprehensive database regarding RES.

Optimum intervals in Table 4.1 indicate at which values of FIT the biggest amount of installed capacities is anticipated. Thus, if FIT scheme to be continued after 2017, FITs should be set inside these intervals. This intervals assume that there are no any caps and restrictions. Nonetheless, there were regressions which were insignificant, though had data, for instance, hydro RES in Germany and the Czech Republic. In this case, we conclude that size of FITs do not really plays a big role in decision making of investors, i.e. investors are more concerned about other factors rather than about FITs. Likewise, regressions resulted in insignificant results in case of Czech wind RES.

Therefore, growth opportunities of renewable energy can be predicted by these intervals and resulting equations of the regressions run.

Likewise, in Chapter 3 various shortcomings related to renewables are discussed and some ways of how to resolve these shortcomings are provided. In addition, in section 3.1.3 we estimated relation between GHG abatement and share of RES.

For the following researchers in the field we would advise to find the missing data for the Czech Republic and do similar analysis. Likewise, find data for other factors, which can affect RES investors in their decision making of whether install capacities of RES or not. For instance, obtain time series for investment costs and/or levelised cost of RES-E. Since, we believe that these factors could have been included in the model, but we could not obtain such data.

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Numerical data used in the thesis is obtained from the following websites[1]:

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The Energy Regulatory Office (ERO) http://www.eru.cz/ [Online; accessed 12-May-2016]

Eurostat http://ec.europa.eu/eurostat/ [Online; accessed 12-May-2016]

National Renewable Energy Action Plan of Germany https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans [Online; accessed 12-May-2016]

National Renewable Energy Action Plan of the Czech Republic https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans [Online; accessed 12-May-2016]

RES LEGAL http://www.res-legal.eu/ [Online; accessed 12-May-2016]

[1] If not stated otherwise

Appendix A

Stata outputs

Table A.1: Stata output for German GHG abatement by RES-E

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	18.21
Model	3.54E+08	1	3.5E+08	Prob >F	0.0008
Residual	2.72E+08	14	1.9E+07	R-squared	0.5653
				Adj R-squared	0.5343
Total	6.27E+08	15	4.2E+07	Root MSE	4410.9
GHGEDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
RESEshareDE	3609.046	845.7903 4.27	0.001	1795.007	5423.086
_cons	-317.18	1820.415 -0.17	0.864	-4221.58	3587.222

Note: ovtest Prob >F = 0.7104; hettest Prob >chi2 = 0.1165;
swilk Prob >Z = 0.0911

Table A.2: Stata output for German GHG abatement by RES-H/C

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	14.65
Model	1.08E+08	1	1.1E+08	Prob >F	0.0018
Residual	1.04E+08	14	7393880	R-squared	0.5113
				Adj R-squared	0.4764
Total	2.12E+08	15	1.4E+07	Root MSE	2719.2
GHGHCDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
RESHCshareDE	3132.254	818.3969 3.83	0.002	1376.967	4887.541
_cons	-290.566	818.1411 -0.36	0.728	-2045.3	1464.172

Note: ovtest Prob >F = 0.1388; hettest Prob >chi2 = 0.5004;
swilk Prob >Z = 0.92334

Table A.3: Stata output for German GHG abatement by RES-H/C

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	923.55
Model	13027681	1	1.3E+07	Prob >F	0
Residual	197484.9	14	14106.1	R-squared	0.9851
				Adj R-squared	0.984
Total	13225166	15	881678	Root MSE	118.77
GHGTDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
RESTshareDE	951.2398	31.30108 30.39	0	884.1057	1018.374
_cons	-6.63744	31.26193 -0.21	0.835	-73.6876	60.41274

Note: ovtest Prob >F = 0.3923; hettest Prob >chi2 = 0.9475;
swilk Prob >Z = 0.13027

Table A.4: Stata output of German regression for hydro RES

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	0.39
Model	4526.865	1	4526.865	Prob >F	0.5426
Residual	162676.1	14	11619.72	R-squared	0.0271
				Adj R-squared	-0.0424
Total	167202.9	15	11146.86	Root MSE	107.79
MWHydroDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITHydroDE	-18.1088	29.01279 -0.62	0.543	-80.33507	44.11741
_cons	211.4045	236.0032 0.90	0.386	-294.7721	717.5811

Note: no tests were done, since regression is insignificant.

Table A.5: Stata output of Czech regression for hydro RES

Source	**SS**	**df**	**MS**	**Number of obs**	**8**
				F(1, 6)	0.33
Model	41.81111	1	41.81111	Prob >F	0.5845
Residual	751.9777	6	125.3296	R-squared	0.0527
				Adj R-squared	-0.1052
Total	793.7888	7	113.3984	Root MSE	11.195
MWhydroCZ	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FIThydroCZ	7.676342	13.29032 0.58	0.585	-24.84389	40.19658
_cons	-15.9082	38.97599 -0.41	0.697	-111.279	79.46259

Note: no tests were done, since regression is insignificant.

Table A.6: Stata output of German regression for landfill, sewage and mine gas RES

Source	**SS**	**df**	**MS**	**Number of obs**	**12**
				F(1, 10)	3.9
Model	85677.72	1	85677.72	Prob >F	0.0765
Residual	219624	10	21962.4	R-squared	0.2806
				Adj R-squared	0.2087
Total	305301.7	11	27754.7	Root MSE	148.2
MWlandfillDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITlandfil~E	643.8705	325.9901 1.98	0.076	-82.48075	1370.222
_cons	-4239.11	2325.79 -1.82	0.098	-9421.292	943.0728

Note: ovtest Prob >F = 0.6085; hettest Prob >chi2 = 0.8844; swilk Prob >Z = 0.18622

Table A.7: Stata output of German regression for geothermal RES

Source	**SS**	**df**	**MS**	**Number of obs**	**12**
				F(1, 10)	1.01
Model	15.53274	1	15.53274	Prob >F	0.3396
Residual	154.4673	10	15.44673	R-squared	0.0914
				Adj R-squared	0.0005
Total	170	11	15.45455	Root MSE	3.9302
MWgeoDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITgeoDE	0.282413	.2816304 1.00	0.34	-0.3450982	0.909925
_cons	-3.40822	5.511267 -0.62	0.55	-15.68808	8.871653

Note: no tests were done, since regression is insignificant.

Table A.8: Stata output of German regression for onshore wind RES

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	6.61
Model	3314183	1	3314183	Prob >F	0.0222
Residual	7015292	14	501092.3	R-squared	0.3208
				Adj R-squared	0.2723
Total	10329475	15	688631.7	Root MSE	707.88
MWonshoreDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITonshoreDE	1090.021	423.8435 2.57	0.022	180.9671	1999.075
_cons	-7703.76	3906.02 -1.97	0.069	-16081.33	673.8246

Note: ovtest Prob >F = 0.0522; hettest Prob >chi2 = 0.0080; swilk Prob >Z = 0.67288

Table A.9: Stata output of German regression for onshore wind RES with polynomial of 2nd order

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(2, 13)	8.02
Model	5706569	2	2853284	Prob >F	0.0054
Residual	4622906	13	355608.2	R-squared	0.5525
				Adj R-squared	0.4836
Total	10329475	15	688631.7	Root MSE	596.33
MWonshoreDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITonshoreDE	49620.89	18714.03 2.65	0.02	9191.685	90050.1
FITonshore~q	-2570.46	991.0165 -2.59	0.022	-4711.42	-429.498
_cons	-236184	88149.72 -2.68	0.019	-426620	-45747.7

Note: ovtest Prob >F = 0.2548; hettest Prob >chi2 = 0.0984; swilk Prob >Z = 0.80035

Table A.10: Stata output of German regression for offshore wind RES

Source	**SS**	**df**	**MS**	**Number of obs**	**7**
				F(1, 5)	7.56
Model	2325630	1	2325630	Prob >F	0.0403
Residual	1538064	5	307612.9	R-squared	0.6019
				Adj R-squared	0.5223
Total	3863694	6	643949	Root MSE	554.63
MWoffshoreDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FIToffshor~E	438.4589	159.4633 2.75	0.04	28.54531	848.3724
_cons	-6702.93	2616.775 -2.56	0.051	-13429.57	23.69948

Note: ovtest Prob >F = 0.0027; hettest Prob >chi2 = 0.0994; swilk Prob >Z = 0.29774

Table A.11: Stata output of German regression for offshore wind RES with polynomial of 2nd order

Source	**SS**	**df**	**MS**	**Number of obs**	**7**
				F(2, 4)	219.9
Model	3828870	2	1914435	Prob >F	0.0001
Residual	34823.56	4	8705.889	R-squared	0.991
				Adj R-squared	0.9865
Total	3863694	6	643949	Root MSE	93.305
MWoffshoreDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FIToffshor~E	-11207.8	886.7051 -12.64	0	-13669.7	-8745.96
FIToffshor~q	353.0522	26.86775 13.14	0	278.4554	427.649
_cons	88725.89	7275.592 12.20	0	68525.61	108926.2

Note: ovtest Prob >F = 0.1291; hettest Prob >chi2 = 0.5067; swilk Prob >Z = 0.37329

Table A.12: Stata output of German regression for offshore wind RES with polynomial of 3rd order

Source	SS	df	MS	Number of obs	7
				F(3, 3)	736.62
Model	3858456	3	1286152	Prob >F	0.0001
Residual	5238.035	3	1746.012	R-squared	0.9986
				Adj R-squared	0.9973
Total	3863694	6	643949	Root MSE	41.785
MWoffshoreDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FIToffshor~E	72632.58	20371.35 3.57	0.038	7801.834	137463.3
FIToffshor~q	-4656.33	1216.998 -3.83	0.031	-8529.36	-783.305
FIToffshor~u	99.41284	24.15052 4.12	0.026	22.55512	176.2706
_cons	-377268	113251.5 -3.33	0.045	-737685	-16851.2

Note: ovtest Prob >F = 0.5667; hettest Prob >chi2 = 0.5080; swilk Prob >Z = 0.65274

Table A.13: Stata output of German regression for biomass RES

Source	SS	df	MS	Number of obs	16
				F(1, 14)	11.46
Model	89203.11	1	89203.11	Prob >F	0.0044
Residual	108981.9	14	7784.421	R-squared	0.4501
				Adj R-squared	0.4108
Total	198185	15	13212.33	Root MSE	88.229
MWbiomassDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITbiomassDE	-19.1608	5.660266 -3.39	0.004	-31.30086	-7.02074
_cons	399.4383	82.66532 4.83	0	222.1388	576.7378

Note: ovtest Prob >F = 0.0544; hettest Prob >chi2 = 0.1122; swilk Prob >Z = 0.61289

Table A.14: Stata output of German regression for biomass RES with polynomial of 2nd order

Source	SS	df	MS	Number of obs	16
				F(2, 13)	13.86
Model	134919.1	2	67459.55	Prob >F	0.0006
Residual	63265.91	13	4866.608	R-squared	0.6808
				Adj R-squared	0.6317
Total	198185	15	13212.33	Root MSE	69.761
MWbiomassDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITbiomassDE	151.2494	55.77982 2.71	0.018	30.74439	271.7543
FITbiomass~q	-6.02677	1.966364 -3.06	0.009	-10.2748	-1.7787
_cons	-713.627	368.9966 -1.93	0.075	-1510.8	83.54147

Note: ovtest Prob >F = 0.6864; hettest Prob >chi2 = 0.3743; swilk Prob >Z = 0.19820

Table A.15: Stata output of German regression for solar RES

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(1, 14)	3.99
Model	25337064	1	25337064	Prob >F	0.0655
Residual	88859997	14	6347143	R-squared	0.2219
				Adj R-squared	0.1663
Total	1.14E+08	15	7613137	Root MSE	2519.4
MWpvDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITPVDE	-154.907	77.53224 -2.00	0.066	-321.1972	11.38301
_cons	9441.761	3542.484 2.67	0.018	1843.888	17039.63

Note: ovtest Prob >F = 0.0000; hettest Prob >chi2 = 0.0711; swilk Prob >Z = 0.05059

Table A.16: Stata output of German regression for solar RES with polynomial of 2nd order

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(2, 13)	16.29
Model	81632652	2	40816326	Prob >F	0.0003
Residual	32564409	13	2504955	R-squared	0.7148
				Adj R-squared	0.671
Total	1.14E+08	15	7613137	Root MSE	1582.7
MWpvDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITPVDE	3863.828	849.1176 4.55	0.001	2029.421	5698.235
FITpvDEsq	-48.0617	10.13821 -4.74	0	-69.9639	-26.1594
_cons	-70916.2	17096.32 -4.15	0.001	-107851	-33981.9

Note: ovtest Prob >F = 0.0005; hettest Prob >chi2 = 0.5904; swilk Prob >Z = 0.61751

Table A.17: Stata output of German regression for solar RES with polynomial of 3rd order

Source	**SS**	**df**	**MS**	**Number of obs**	**16**
				F(3, 12)	23.23
Model	97424828	3	32474943	Prob >F	0
Residual	16772233	12	1397686	R-squared	0.8531
				Adj R-squared	0.8164
Total	1.14E+08	15	7613137	Root MSE	1182.2
MWpvDE	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITPVDE	24675.01	6223.685 3.96	0.002	11114.76	38235.25
FITpvDEsq	-554.44	150.8367 -3.68	0.003	-883.085	-225.795
FITpvDEcu	4.029787	1.198853 3.36	0.006	1.417711	6.641863
_cons	-350005	84004.61 -4.17	0.001	-533035	-166974

Note: ovtest Prob >F = 0.0611; hettest Prob >chi2 = 0.8394; swilk Prob >Z = 0.56411

Table A.18: Stata output of Czech regression for solar RES with polynomial of 4th order

Source	**SS**	**df**	**MS**	**Number of obs**	**13**
				F(5, 7)	74.82
Model	2067825	5	413565.1	Prob >F	0
Residual	38692.84	7	5527.548	R-squared	0.9816
				Adj R-squared	0.9685
Total	2106518	12	175543.2	Root MSE	74.347
MWpvCZ	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
FITpvCZqu	-0.69811	.1704983 -4.09	0.005	-1.101274	-0.29495
FITpvCZcu	16.12037	4.297576 3.75	0.007	5.958221	26.28252
FITpvCZsq	-107.27	35.03922 -3.06	0.018	-190.1249	-24.4157
FITpvCZ	228.8294	101.4919 2.25	0.059	-11.16089	468.8196
CZdummy	913.9999	137.9842 6.62	0	587.7191	1240.281
_cons	-64.4934	74.32014 -0.87	0.414	-240.2327	111.2458

Note: ovtest Prob >F = 0.0412; hettest Prob >chi2 = 0.8321; swilk Prob >Z = 0.06579